LAND-USE AND LAND-COVER CHANGE FROM 1974 to 2008 AROUND MOBILE BAY

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Abstract

This project is a Gulf of Mexico Application Pilot in which NASA Stennis Space Center (SSC) is working within a regional collaboration network of the Gulf of Mexico Alliance. NASA researchers, with support from the NASA SSC Applied Science Program Steering Committee, employed multi-temporal Landsat data to assess land-use and land-cover (LULC) changes in the coastal counties of Mobile and Baldwin, AL, between 1974 and 2008. A multi-decadal time-series, coastal LULC product unique to NASA SSC was produced. The geographic extent and nature of change was quantified for the open water, barren, upland herbaceous, non-woody wetland, upland forest, woody wetland, and urban landscapes. The National Oceanic and Atmospheric Administration (NOAA) National Coastal Development Data Center (NCDDC) will assist with the transition of the final product to the operational end user, which primarily is the Mobile Bay National Estuary Program (MBNEP).

We found substantial LULC change over the 34-year study period, much more than is evident when the change occurring in the last years. Between 1974 and 2008, the upland forest landscape lost almost 6% of the total acreage, while urban land cover increased by slightly more than 3%. With exception to open water, upland forest is the dominant landscape, accounting for about 25-30% of the total area.

Background

The purpose of this project is to quantify and assess geospatial LULC changes in the coastal counties of Mobile and Baldwin, AL. These counties surround Mobile Bay, which has the fourth largest freshwater inflow in the United States. The Mobile Bay estuary is economically important to the Nation in terms of shipping, fishing, and recreation. It is environmentally important in multiple ways; for example, it provides vital nursery habitat for commercially and recreationally important fish species. The region also has exceptional aquatic and terrestrial biodiversity. The health of the estuary is influenced by changing land-use patterns, much of which has been attributed to urbanization since Hurricane Frederic in 1979. Mobile Bay has been identified by participants of the Gulf of Mexico Research Requirements Planning Workshop (AL and MS) as an area of critical study. The Mobile Bay estuary was selected by NASA SSC and its partners as a region for investigation because of the observed anthropogenic changes in recent decades and because of its environmental diversity and ecological importance. This work is supported by several Federal, state, and locally led research projects currently active in Mobile Bay, Grand Bay, Weeks Bay, and the Mississippi Sound.

Objectives

1. Survey the needs of the Mobile Bay coastal environmental managers to formulate a project topic.
2. Primary research objective: For NASA SSC to create historic and current LULC change detection products of Mobile Bay to provide to the coastal environmental managers and to the public.
   a. Create NASA-specific LULC data and data products for Mobile Bay using methods that could be applied to other coastal regions, especially within the Gulf of Mexico.
   b. Determine decadal-scale urban expansion and areas of interest, the latter regions determined by MBNEP.
3. Transfer data to end users and NOAA-NCDDC.
4. Establish and maintain communication with and seek guidance from our federal and Mobile Bay coastal environmental manager partners.

Methods

Target dates for products (MB LULC, herein) were determined using two criteria: 1) Correspondence with pre-existing Federal agency LULC classification products (National Wetlands Inventory, NWI; National Land Cover Database, NLCD; and Coastal Change Analysis Program, C-CAP); and 2) End users' requirements. Figure 1 shows a timeline indicating the NASA LULC products, major hurricanes impacting the Mobile Bay region, and the major pre-existing LULC products.

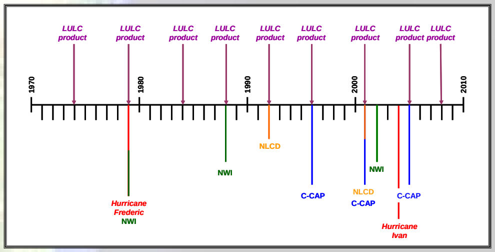

Figure 1. Temporal distribution of nine LULC NASA SSC products that were produced based on Landsat data. Timeline also shows the dates when other classification schemes to identify either wetland or upland change have been published: NWI, NLCD, and C-CAP.

Table 1. Landsat data used for LULC classifications.

Year	Sensor / Resolution	Collection Date
1974	Landsat MSS / 60 m	11/12/1974
1979	Landsat MSS / 60 m	10/26/1979
1984	Landsat MSS / 60 m	09/06/1984
1988	Landsat TM / 30 m	02/22/1988
1991	Landsat TM / 30 m	09/26/1991
1996	Landsat TM / 30 m	01/27/1996
2001	Landsat ETM / 30 m	03/05/2001
2005	Landsat TM / 30 m	03/24/2005
2008	Landsat TM / 30 m	03/16/2008

Landsat MSS (Multispectral Scanner), Landsat TM (Thematic Mapper), and Landsat ETM (Enhanced Thematic Mapper) data were obtained (Table 1). Each Landsat scene was pre-processed by co-registering to a "master" orthorectified Landsat scene originally acquired 26 September 1991. Geo-corrected Landsat data was rescaled to planetary reflectance for computing Normalized Difference Vegetation Index (NDVI) data products. The latter were occasionally used as collateral data in evaluating and refining the LULC products. Geo-corrected raw data were used as the primary data source for producing the LULC products.

Each LULC product was based primarily upon classification of one date of Landsat data using ERDAS IMAGINE® for image processing and analysis. Classification was performed using a hybrid unsupervised/supervised approach. Initially, a given Landsat dataset was subjected to unsupervised classification using ISODATA clustering with 20 total clusters, convergence set to 0.995 (on scale of 0 to 1), 100 iterations, and cluster means initialization along the principal axis (c.f., (Leica Geosystems, 2005, for ISODATA details). The resulting classification was recoded into water, forest-dominated land, and non-forest dominated land. This "first cut" classification was used to isolate raw data into two subsets of forest-dominated and non-forest dominated raw data, respectively. These two raw data subsets were subjected to unsupervised classification, clustering to 16 classes for the forest-dominated raw data and 20 cluster classes for the non-forested raw data. These cluster classes of the aforementioned classifications were described with respect to the LULC scheme. Some of the clusters pertained to multiple LULC categories. The raster attribute table for each classification was edited to include an attribute column for each LULC category. Table 2 shows the NASA LULC classes in relation to the C-CAP classification scheme. On a per-cluster class basis, we assigned a value of one to the attribute column for each LULC class when the cluster included that LULC category. On a per-cluster class basis, we assigned a value of zero to the attribute column for each LULC class when the cluster class did not pertain to a given LULC class.

Table 2. Comparison of land use and land cover classifications employed by NOAA C-CAP's program and our MB LULC project.

C-CAP LULC Class	Corresponding MB LULC Class	C-CAP LULC Class	Corresponding MB LULC Class
Uplands	***Uplands***	***Wetlands***	***Wetlands***
Developed, high intensity	Urban	Palustrine forested wetland	Woody Wetland
Developed, medium intensity	Urban	Palustrine scrub/shrub wetland	Woody Wetland
Developed, low intensity	Urban	Palustrine emergent wetland	Non-Woody Wetland
Developed, open space	Urban	Estuarine forested wetland	Woody Wetland
Cultivated crops	Upland Herbaceous	Estuarine scrub shrub wetland	Woody Wetland
Pasture/hay	Upland Herbaceous	Estuarine emergent wetland	Non-Woody Wetland
Grassland/ herbaceous	Upland Herbaceous	Tundra	
Sedge/herbaceous		Perennial Ice/snow	
Deciduous forest	Upland Woods	Moss	
Evergreen forest	Upland Woods	***Other***	***Other***
Mixed forest	Upland Woods	Water	Open Water
Scrub/Shrub	Upland Woods	Unconsolidated shore	Open Water
Dwarf scrub		Palustrine aquatic bed	Open Water
Barren land	Barren	Estuarine aquatic bed	Open Water

Spatial models were constructed to produce binary masks of each targeted LULC class. C-CAP products were used to reduce classification confusion of certain targeted classes; in particular, urban, woody wetlands, and non-woody wetlands. C-CAP LULC data products for 1996, 2001, and 2005 (pre-Hurricane Katrina) were recoded into the same seven classes as used in the aforementioned Landsat classifications. Maximum extent images of urban, woody wetlands, and non-woody wetland LULC categories were computed from the union of the 1996, 2001, and 2005 extent of each applicable category. At this point, these masks were not completely mutually exclusive; additional editing was performed using a maximum value compositing approach to compute a discrete, thematic wall-to-wall refined classification.

To compute a complete LULC classification for each targeted date, a spatial model was implemented to merge the individual classifications of LULC classes into a wall-to-wall product. This model used a maximum value compositing technique in which certain LULC categories were weighted higher in order to reduce classification confusion. If needed, additional classification refinement was completed to reduce visible classification error. Such refinement usually was done by reclassification of an identified problematic class, generally using raw data masking and cluster busting techniques described by Jensen (1996). Summary area tables were produced for each LULC classification (one for each targeted date). The classification products were also subset to derive additional products for watershed areas of interest: D'Olive Bay, Three Mile Creek, Upper Fish River, Dog River, and Northern Big Creek. A subset of the study area in northern Mobile Bay was selected and used for demonstration purposes.

Results and Discussion

Nine single date LULC maps were produced showing the spatial distribution of seven landscape types in Mobile and Baldwin counties. Figure 2 shows the LULC products for 1974 (left) and 2008 (right), the temporal extremes of this project. The geospatial extent of each cover type for all data products is shown in Table 3. The most striking qualitative (visual) change between the LULC in 1974 and 2008 is the urban expansion around the city of Mobile and along the Eastern Shore. In the northeast portion of the study region, there has been a transition from upland forest to the upland herbaceous land cover. However, Table 3 shows that the aforementioned land cover transition has been temporally variable.

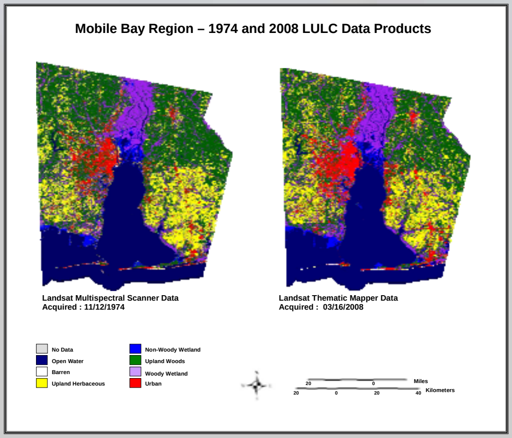

Figure 2. Landsat-derived land-use and land-cover data product for 1974 (left) and 2008 (right) showing surveyed area within Mobile and Baldwin counties.

Table 3. Landsat-derived geospatial statistics for Landsat surveyed portions of Mobile and Baldwin counties.

Class	Coverage (acres) – Mobile and Baldwin Counties								
	1974	1979	1984	1988	1991	1996	2001	2005	2008
Open Water	450543	461839	462655	463506	464225	460829	469246	471609	465750
Barren	2521	4058	4492	2672	4965	4709	7046	7731	5305
Upland Herbaceous	180295	265938	158592	257969	254973	282511	258913	159564	197118
Non-Woody Wetland	37475	42214	30139	33749	36321	36081	34430	32964	35080
Upland Forest	493301	359217	480289	390702	388236	340497	347224	442474	406703
Woody Wetland	203704	213013	210440	196284	195727	215731	218139	217327	210192
Urban	80972	102416	102400	104125	104338	108455	113815	117144	128664

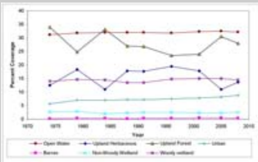

Figure 3. Percent coverage for each LULC class for Mobile and Baldwin counties.

Percent coverage for each class throughout the study period for Mobile and Baldwin counties for each landscape is shown in Figure 3. Upland forest and open water are the most dominant LULC types, at around 30% throughout the study period; however, the open water class is more consistent through time. Upland forest and upland herbaceous are the most dynamic land covers. These classes have an inverse relationship, thus suggesting that the two transition between each other. However, because the data were computed for the entire study area (and no pixel-by-pixel time series was constructed), we are not able to conclude whether individual parcels of land are "flipping" between upland herbaceous and upland forest. The dynamism within the upland herbaceous and upland forest land covers is most dramatic between 1974 and 1984.

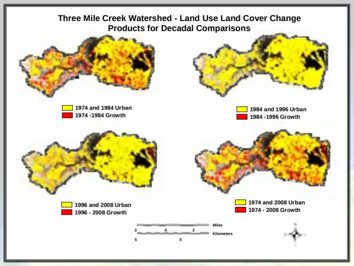

Figure 4. LULC change on the decadal scale and for the 34-year study period: Three Mile Creek.

References

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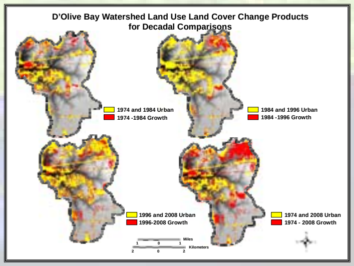

Figure 5. Land use land cover change on the decadal scale and for the 34-year study period - D'Olive Bay.

LULC maps and change statistics were calculated for all the watersheds of interest. Three Mile Creek (Figure 4) and D'Olive Bay (Figure 5) are shown here as examples because of their different characteristics. D'Olive Bay area has moderate amounts of upland forested landscape subject to urban sprawl, while Three Mile Creek is largely urbanized. Considering the entire watershed, Three Mile Creek showed approximately 90% of the total urban expansion, and loss of upland forest between 1974-1984. D'Olive Bay also experienced comparable urban expansion between 1974-1984. However, between 1984-1996 there was a decrease in urbanized areas and an increase of upland forested land. The details of this anomaly, including the drivers for change, warrant more investigation.

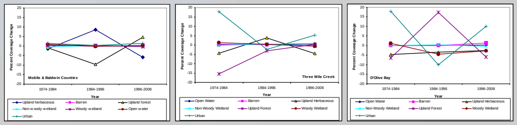

Figure 6. Decadal LULC change for Mobile and Baldwin counties (left), Three Mile Creek (middle), and D'Olive Bay (right).

Figure 6 shows the decadal percent coverage change for Mobile and Baldwin Counties (left), Three Mile Creek (middle), and D'Olive Bay (right). The inverse relationship between upland forest and upland herbaceous (Figure 3) is still prevalent on the decadal scale, shown in Figure 6. This general relationship is also observed for the mainly forested D'Olive Bay watershed; however, the landscapes involved are urban and upland forest. Three Mile Creek, which is highly urbanized, has a more complicated change pattern because there is a inverse relationship between urban and upland herbaceous, with the upland forest following the trends of upland herbaceous through the second decade, with a divergence during decade three.

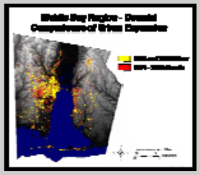

Figure 7. Urban change from 1974 to 2008 for Mobile and Baldwin counties.

Table 4. Geospatial trends in urban expansion for Mobile and Baldwin counties from 1974-2008, based on Landsat data analysis. Converted acres indicate the total acres converted from the 1974 class to urban in 2008.

1974 Class → 2008 Class	1974 Class Acres	Converted Acres	Percent Converted Acres
Open water → Urban	450543	412	0.32
Barren → Urban	2521	241	0.19
Upland herbaceous → Urban	180295	9570	7.44
Non-woody wetland → Urban	37475	769	0.60
Upland forest → Urban	493301	44182	34.34
Woody wetland → Urban	203704	2663	2.07
Urban → Urban	80972	70825	55.05

Table 4 shows the conversion of the LULC classes to the urban landscape for Mobile and Baldwin counties between 1974 and 2008. Approximately 55% of the study area was classified as urban in 1974 and 2008, thus indicating that over the entire study period, approximately 45% of the Mobile and Baldwin region that was urban in 2008 was non-urban in 1974. A majority of the conversion to urban came from upland forest (~34%) followed by upland herbaceous (~7%). Figure 7 shows urban expansion for Mobile and Baldwin counties.

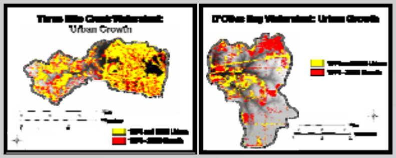

Figure 8. Urban expansion for Three Mile Creek (left)) and D'Olive Bay (right).

Urban growth between 1974 and 2008 for D'Olive Bay and Three Mile Creek is shown in Figure 8. For Three Mile Creek, the amount of urbanization in 1974 is quite evident. For the D'Olive Bay watershed, however, the urban expansion is much less universal than for Three Mile Creek, with significant urbanization in the northeast portion of the watershed.

Table 5 summarizes accuracy assessment for the 1979, 1996, 2001, 2005, and 2008 LULC classifications. The overall accuracy varied from 83.13 (for 2005) to 89.33 (for 1979), and the Kappa values for these classifications ranged from 0.78 (for 2005) to 0.87 (for 1979). The sampling intensity for these assessments ranged from 150 (for 1979) to 190 (for 2008) total random samples per classification. In all cases, the overall accuracy exceeded 80% and the Kappa either approached or exceeded 0.8 (on a scale of 0 to 1). Interestingly, the use of Landsat MSS data (1979, at 60 m, rather than post 1984 at 30 m) did not seem to lower the accuracy. However, we acknowledge only one MSS product was assessed for accuracy and additional accuracy assessment is required. Spatial models were constructed to produce binary masks of each targeted LULC class. C-CAP products were used to reduce classification confusion of certain targeted classes; in particular, urban, woody wetlands, and non-woody wetlands. C-CAP LULC data products for 1996, 2001, and 2005 (pre-Hurricane Katrina) were recoded into the same seven classes as used in the aforementioned Landsat classifications. Maximum extent images of urban, woody wetlands, and non-woody wetland LULC categories were computed from the union of the 1996, 2001, and 2005 extent of each applicable category. At this point, these masks were not completely mutually exclusive; additional editing was performed using a maximum value compositing approach to compute a discrete, thematic wall-to-wall refined classification.

Table 5. Overall accuracy of 1979, 1996, 2001, 2005, and 2008 LULC classifications compared to available reference data.

Year	Overall Accuracy	Overall Kappa	Total Samples
1979	89.33	0.87	150
1996	86.88	0.84	160
2001	88.00	0.85	150
2005	83.13	0.78	160
2008	89.06	0.86	192

An additional accuracy assessment was completed for the 2005 C-CAP product produced prior to Hurricane Katrina. The 2005 C-CAP classification yielded an overall accuracy of 86.25% compared to the 2005 Landsat result of 83.13% overall accuracy. The C-CAP product produced a higher overall Kappa value of 0.83 compared to the Landsat result of 0.78. The C-CAP and the Landsat classification were both assessed using 160 randomly sampled points. The higher relative accuracy of the C-CAP product was expected, in part due to C-CAP employing multiple Landsat dates to produce the classification, and in part due to the C-CAP process being more labor and resource intensive. The 2005 Landsat product was one of the first products produced in this study, which may also partially help explain its lower accuracy. However, even as is, the overall accuracy of all of the non-C-CAP products appears to be acceptable.

Conclusions

This project was a joint effort between NASA and MBNEP. All project-relevant geospatial data and final data products have been transferred to MBNEP and will be transferred to NOAA-NCDDC. All NASA-generated products will be available for NOAA Integrated Ecosystem Assessments. The products from this Pilot Project will help MBNEP make conservation and restoration decisions in the future.